Environmental Issues and World Energy Use

In the coming decades, global environmental issues could significantly affect patterns of energy use around the world. Any future efforts to limit carbon emissions are likely to alter the composition of total energy-related carbon emissions by energy source.

This chapter examines the link between energy use and the environment worldwide, with particular emphasis on the *International Energy Outlook 2001* (*IEO2001*) projections for energy consumption and associated carbon dioxide emissions over the next 20 years. Regulations to reduce regional energy-related emissions of sulfur dioxide and nitrogen oxides, which are linked to several environmental problems, are also discussed (see box on page 170).

Global climate change is a wide-reaching environmental issue. The ongoing debate over climate change and how it should be addressed is a prime example of the divergence between concerns about energy supply and the environment. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human-caused) sources: the combustion of fossil fuels and land-use changes. Net carbon dioxide releases from these two sources are believed to be contributing to the rapid rise in atmospheric concentrations since pre-industrial times[***1***]. Because estimates indicate that approximately three-quarters of all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate [***2***].

For some time, fossil fuels have accounted for most of the energy consumed worldwide. Low fossil fuel prices relative to other energy forms have been a major factor underlying this circumstance. In 2000, when world oil prices increased, consumers in many countries were most noticeably affected at the gasoline pump. From an environmental standpoint, the gasoline price increase could be viewed in a positive light: higher prices have the potential to discourage fuel consumption, thereby reducing carbon dioxide and other tailpipe emissions. However, the price increase illustrates the conflict that often arises between energy use (in this case oil consumption) and environmental concerns such as climate change.

The higher gasoline prices of 2000 were generally not well received. In Western Europe, truck drivers, farmers, and taxi drivers launched protests against high motor fuel prices in the fall of 2000. In the United States, efforts to alleviate the temporarily tight market supply and bring down prices prompted support for releasing oil from the Strategic Petroleum Reserve. The recent price spikes also increased calls for opening up parts of the Arctic National Wildlife Refuge in Alaska for oil and gas development as part of a long-term approach to increasing domestic energy supply; but oil drilling in such ecologically sensitive areas has also been opposed on environmental grounds, illustrating the tradeoffs between energy supply and the environment.

Another environmental issue with implications for world energy markets is the movement of crude oil from source to market. Marine ecosystems are potentially vulnerable to an aging tanker fleet, as evidenced by several recent spills from oceangoing tankers carrying crude oil. In December 1999, the oil tanker Erika broke in half off the coast of Brittany, spilling 3 million gallons of crude oil. In November 2000, more than a half million gallons of crude spilled from a tanker into the lower Mississippi River in Louisiana after an explosion in the tanker's engine caused it to run aground. The U.S. Supreme Court recently rejected an appeal by ExxonMobil against the $5 billion in punitive damages it was ordered to pay after the Valdez tanker ran aground in Alaska in 1989; however, neither public outcry nor threats of litigation have prompted many tanker owners to invest in adjustments (such as double-hull fittings) that would lessen the chances of damaging spills.

Nuclear energy continues to face strong opposition in some areas. Key issues are the safety of nuclear power plant operations, the environmental hazards presented by spent fuel transportation and storage, and the possibility of radioactive releases in the event of nuclear accidents. Austrians protested the startup of a Soviet-designed nuclear power plant in the town of Temelin, Czech Republic, 30 miles from the Austrian border. The nuclear plant began operating in October 2000, despite threats by the Austrian government to block the Czech Republic's entry into the European Union (EU). Concurrently, protests were held in Germany over the lifting of a ban on nuclear waste shipments. The German government imposed the ban 2 years ago when it was revealed that nuclear waste transport containers from past shipments had leaked radiation well above permitted levels. Safety concerns associated with nuclear energy have also been in the spotlight in Japan, the United States, and other countries worldwide.

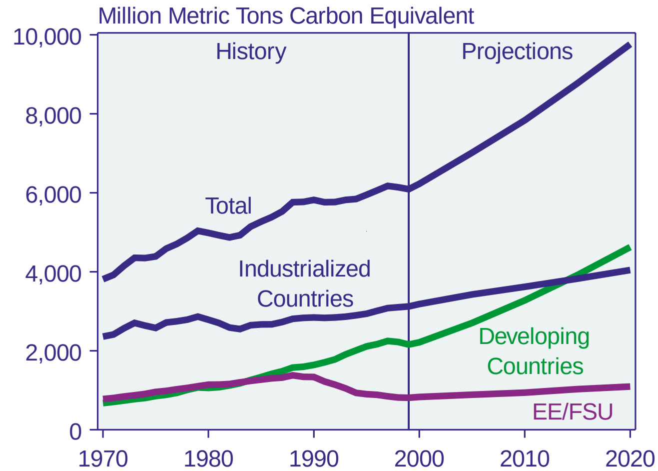
Global Outlook for Carbon Dioxide Emissions

Carbon dioxide emissions from fossil fuel combustion worldwide increased from 3,811 million metric tons of carbon equivalent in 1970 to 5,821 million in 1990 (Figure 94)—an average annual rate of growth rate of 2.1 percent.[29] Between 1990 and 1999, however, the growth in carbon dioxide emissions slowed to an average annual rate of 0.5 percent per year. Reasons for the slower growth included a 1991 economic recession in the United States that induced a temporary drop in energy use. In Eastern Europe and the former Soviet Union (EE/FSU), political and economic upheaval led to a sharp downturn in energy use that continued through most of the decade. In Western Europe, emissions dropped between 1990 and 1994 as a result of cutbacks in coal use and increasing reliance on nuclear energy. And in the late 1990s, widespread economic recession in Southeast Asia slowed the region's rapidly expanding use of fossil fuels.

Based on expectations of regional economic growth and energy demand in the *IEO2001* reference case, global carbon dioxide emissions are expected to grow more quickly over the projection period than they did during the 1990s. Increases in fossil fuel consumption in developing countries and the EE/FSU are largely responsible for the expectation of fast-paced growth in carbon dioxide emissions. In the EE/FSU and industrialized nations, reductions in non-carbon-emitting nuclear power are expected to lead to corresponding increases in fossil fuel use. Projected increases in natural gas use in Central and South America also contribute to the projected growth of carbon dioxide emissions over the forecast horizon.

World carbon dioxide emissions are projected to reach 9,762 million metric tons carbon equivalent in 2020, reflecting an increase of 3,671 million metric tons over 1999 emissions. Approximately 67 percent of the growth in emissions between 1999 and 2020 is projected to come from developing countries, where population growth, rising personal incomes, rising standards of living, and further industrialization are expected to have a much greater influence on levels of energy consumption than in industrialized countries. Energy-related emissions in China, the country expected to have the highest rate of growth in per capita income and electricity use over the forecast period, are projected to constitute 28 percent of the global increase in carbon dioxide emissions over the forecast period. In comparison, the industrialized nations are expected to account for 25 percent of the total increase in emissions and the EE/FSU region 8 percent.

Figure 94. World Carbon Dioxide Emissions by Region, 1970-2020



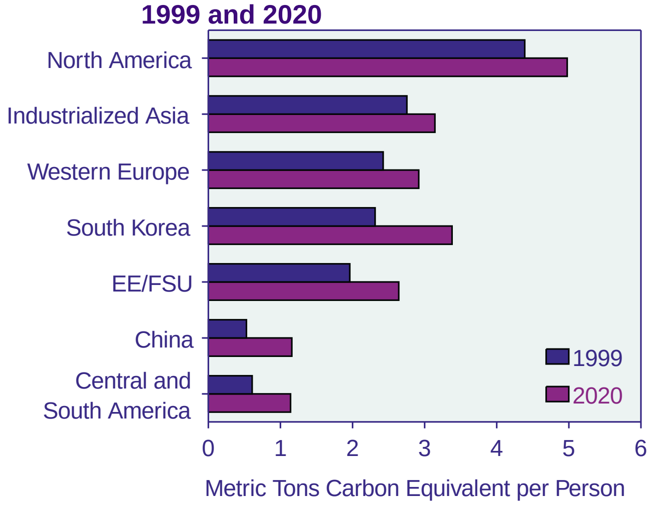
Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

In 1999, carbon dioxide emissions from the industrialized countries accounted for 51 percent of the global total, followed by developing countries at 35 percent and the EE/FSU at 13 percent. By 2020, however, the developing countries are projected to account for the largest share (47 percent) of world carbon dioxide emissions. Still, emissions per capita in the industrialized countries are expected to remain well above the levels in most developing countries, with the exception of South Korea (Figure 95).

Future levels of energy-related carbon dioxide emissions are likely to differ significantly from *IEO2001* projections if measures to stabilize atmospheric concentrations of global greenhouse gases are enacted, such as those outlined under the Kyoto Protocol of the Framework Convention on Climate Change. The Protocol, which calls for limitations on emissions of greenhouse gases (including carbon dioxide) for developed countries and some countries with economies in transition, could have profound effects on future fuel use worldwide. As of February 2001, the Protocol had been ratified by only 32 of the Parties to the United Nations Framework Climate Change Convention (UNFCCC), none of which would be required to reduce emissions under

[29] Carbon dioxide emissions from energy use are reported here in metric tons carbon equivalent. One million metric tons carbon equivalent is equal to 3.667 million metric tons of carbon dioxide.

Figure 95. Per Capita Carbon Dioxide Emissions in Selected Regions and Countries, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2020:** EIA, World Energy Projection System (2001).

the terms of the treaty.[30] Consequently, *IEO2001* projections do not reflect the potential effects of the Kyoto Protocol or any other proposed climate change policy measures.

Factors Influencing Trends in Energy-Related Carbon Emissions

The *Kaya Identity* is a mathematical expression that is used to describe the relationship among the factors that influence trends in energy-related carbon dioxide emissions:

$$C = (C / E) \times (E / GDP) \times (GDP / POP) \times POP \quad .$$

The formula links total energy-related carbon emissions (C) to energy (E), the level of economic activity as measured by gross domestic product (GDP), and population size (POP) [***3***]. The first two components on the right-hand side represent the carbon intensity of energy supply (C/E) and the energy intensity of economic activity (E/GDP), as discussed below. Economic growth is viewed from the perspective of changes in output per capita (GDP/POP). At any point in time, the level of energy-related carbon emissions can be seen as the product of the four Kaya Identity components—energy intensity, carbon intensity, output per capita, and population.

The *carbon intensity of energy supply* is a measure of the amount of carbon associated with each unit of energy produced. It directly links changes in carbon dioxide emissions levels with changes in energy usage. Carbon dioxide emissions vary by energy source, with coal being the most carbon-intensive fuel, followed by oil, then natural gas. Nuclear power and some renewable energy sources (i.e., solar and wind power) do not generate carbon dioxide emissions. As changes in the fuel mix alter the share of total energy demand met by more carbon-intensive fuels relative to less carbon-intensive or “carbon-free” energy sources, overall carbon intensity changes. For example, coal use for electricity generation in Western Europe was increasingly replaced by natural gas and nuclear power during the early 1990s. As a result, the region’s total energy-related carbon dioxide emissions declined more rapidly than its energy use increased, and the overall level of carbon intensity for Western Europe declined steadily during the period.

The *energy intensity of economic activity* is a measure of energy consumption per unit of economic activity. Increased energy use and economic growth generally occur together, although the degree to which they are linked varies across regions and stages of economic development. In industrialized countries, growth in energy demand has historically lagged behind economic growth, whereas the two are more closely correlated in developing countries.

Regional energy intensities, like carbon intensities, may change over time. For example, changes in the overall energy efficiency of an economy’s capital stock (vehicles, appliances, manufacturing equipment, buildings, etc.) affect trends in its energy intensity. Although new stock is often more energy efficient than the older equipment it replaces, the rate of efficiency improvement in an economy is also affected by the availability of more energy-efficient technologies, the rate of capital stock turnover, the dynamics between energy and non-energy prices, investment in research and development, and the makeup of the existing capital stock.

Structural shifts in national or regional economies can also lead to changes in energy intensity, when the shares of economic output attributable to energy-intensive and non-energy-intensive industries change. For example, iron and steel production, chemicals manufacturing, and mining are among the most energy-intensive industrial activities, and countries whose economies rely on production from such energy-intensive industries tend

[30] The Kyoto Protocol will enter into force 90 days after it has been ratified by at least 55 Parties to the UNFCCC, including developed countries representing at least 55 percent of the total 1990 carbon dioxide emissions from this group. The following Parties to the Convention had ratified the Protocol as of February 5, 2001: Antigua and Barbuda, Azerbaijan, Bahamas, Barbados, Bolivia, Cyprus, Ecuador, El Salvador, Equatorial Guinea, Fiji, Georgia, Guatemala, Guinea, Honduras, Jamaica, Kiribati, Lesotho, Maldives, Mexico, Micronesia, Mongolia, Nicaragua, Niue, Palau, Panama, Paraguay, Samoa, Trinidad and Tobago, Turkmenistan, Tuvalu, Uruguay, and Uzbekistan.

to have high energy intensities. When their economies shift toward less energy-intensive activities, their energy intensities may decline. Other influences on regional energy intensity trends include changes in consumer tastes and preferences, taxation, the availability of energy supply, government regulations and standards, and the structure of energy markets themselves.

The Kaya Identity provides an intuitive approach to the interpretation of historical trends and future projections of energy-related carbon dioxide emissions. Essentially, it illustrates how the percentage rate of change in carbon dioxide emission levels over time approximates the percentage rate of change across the four Kaya components.[31] Between 1970 and 1999, both the industrialized world and the developing world had positive annual average growth rates in carbon dioxide emissions, because declines in energy intensity and carbon intensity were outpaced by economic growth and population growth (Table 23). The trend was similar in the EE/FSU region except during the 1990s, when declines in carbon intensity and energy intensity were coupled with a severe drop in economic output per capita. Carbon emissions in the EE/FSU region declined by an average of 5.4 percent per year during the 1990s.

In the *IEO2001* reference case projections for regional carbon dioxide emissions, economic growth and population growth continue to overshadow expected reductions in energy intensity and carbon intensity, particularly in the developing world. Accordingly, future reductions in carbon emissions would require accelerated declines in energy intensity and/or carbon intensity (for example, by increasing the share of energy demand met by low-carbon or carbon-free energy sources). Such changes may in turn require significant changes in existing energy infrastructures. The Kaya Identity does not provide a framework for estimating economic costs associated with any efforts to reduce either carbon intensity or energy intensity.

Table 23. Average Annual Percentage Change in Carbon Dioxide Emissions and the Kaya Identity Components by Region, 1970-2020

Parameter	History			Reference Case Projections	
	1970-1980	1980-1990	1990-1999	1999-2010	2010-2020
Industrialized World					
Carbon Intensity	-0.5%	-0.7%	-0.5%	0.0%	0.1%
Energy Intensity	-1.1%	-2.0%	-0.7%	-1.3%	-1.3%
Output per Capita	2.4%	2.2%	1.6%	2.2%	2.0%
Population	0.9%	0.7%	0.6%	0.5%	0.4%
Carbon Emissions	1.7%	0.2%	1.0%	1.4%	1.1%
Developing World					
Carbon Intensity	-0.8%	-0.2%	-0.7%	-0.1%	-0.1%
Energy Intensity	-0.4%	0.9%	-1.0%	-1.4%	-1.4%
Output per Capita	3.5%	1.7%	3.1%	3.7%	4.2%
Population	2.2%	2.1%	1.7%	1.7%	0.8%
Carbon Emissions	4.6%	4.5%	3.1%	3.9%	3.5%
Eastern Europe and the Former Soviet Union					
Carbon Intensity	-0.8%	-0.3%	-1.0%	-0.2%	-0.3%
Energy Intensity	1.4%	0.6%	-0.5%	-2.4%	-2.6%
Output per Capita	2.4%	0.6%	-4.0%	4.1%	4.5%
Population	0.9%	0.7%	0.0%	0.0%	0.0%
Carbon Emissions	3.9%	1.6%	-5.4%	1.4%	1.5%

Note: Using an average annual rate of change in carbon emissions between any two years mathematically approximates the actual combined effect on emission levels from changes in the four Kaya Identity components. Across years where there were large changes in either carbon emission levels or the Kaya Identity components themselves, comparisons based on an average annual rate of change measure may yield round-off differences.

Sources: **History:** Energy Information Administration (EIA), Office of Energy Markets and End Use, International Statistics Database and *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

[31] In terms of rates of changes, the Kaya Identity can be expressed as $[d(\ln C) \,/\, dt = d(\ln C/E) \,/\, dt + d(\ln E \,/\, GDP) \,/\, dt + d(\ln GDP \,/\, POP) \,/\, dt + d(\ln POP) \,/\, dt]$, which shows that, over time, the rate of change in carbon emissions is equal to the sum of the rate of change across the four Kaya components (i.e. the rate of change in carbon intensity, plus the rate of change in energy intensity, plus the rate of change in output per capita, plus the rate of change in population).

Regional Trends

Industrialized Countries

In the industrialized world, half of all energy-related carbon dioxide emissions in 1999 came from oil use, followed by coal at 30 percent. Oil is projected to remain the primary source of carbon dioxide emissions in the industrialized countries throughout the projection period because of its continued importance in the transportation sector, where there are currently few economical alternatives. Natural gas use and associated carbon dioxide emissions are projected to increase substantially between 1999 and 2020 (Figure 96), particularly in the electricity sector.

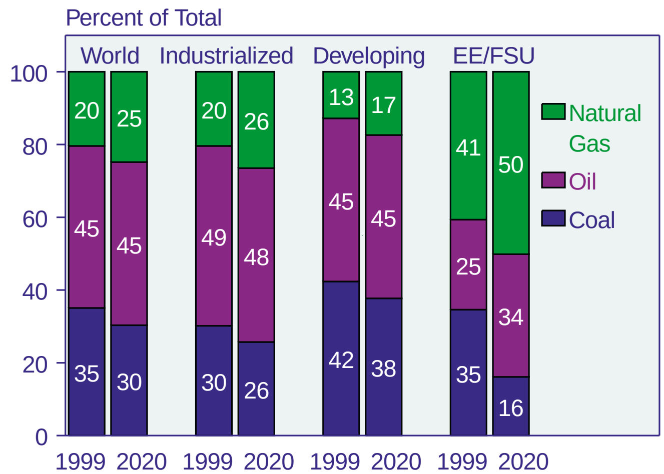
Energy-related carbon dioxide emissions from the United States accounted for approximately one-half of the carbon emissions from industrialized countries throughout the 1990s. U.S. carbon dioxide emissions increased steadily over the decade (with the exception of 1991). In Western Europe, carbon dioxide emissions dropped between 1990 and 1994, largely as a result of decreasing coal consumption in Germany and the United Kingdom. In Japan, emissions fell after 1996, when a major economic slowdown and recession led to reductions in energy use (Figure 97). Given expectations for economic growth over the forecast period (including Japan, whose economy is expected to recover), carbon dioxide emissions from the industrialized world are projected to increase at a faster pace than during the 1990s.

North America

In North America, strong economic growth was the main factor underlying the growth in energy consumption and carbon dioxide emissions during the 1990s. The United States held a steady 84-percent share of the continent's total energy consumption during the 1990s. U.S. carbon intensity is projected to increase in the *IEO2001* reference case, primarily because of expected changes in the fuel mix for electricity generation. Natural gas and coal use for electricity generation are projected to increase, whereas generation from nuclear energy is expected to decline toward the end of the forecast period with the retirement of some nuclear power capacity. As a result, U.S. electricity generation is projected to become more carbon intensive over the forecast period. In total, annual energy-related carbon dioxide emissions in the United States are projected to increase by about 35 percent between 1999 and 2020, with fossil fuel use for electricity generation and transportation expected to continue as the source of most of the country's energy-related carbon dioxide emissions.

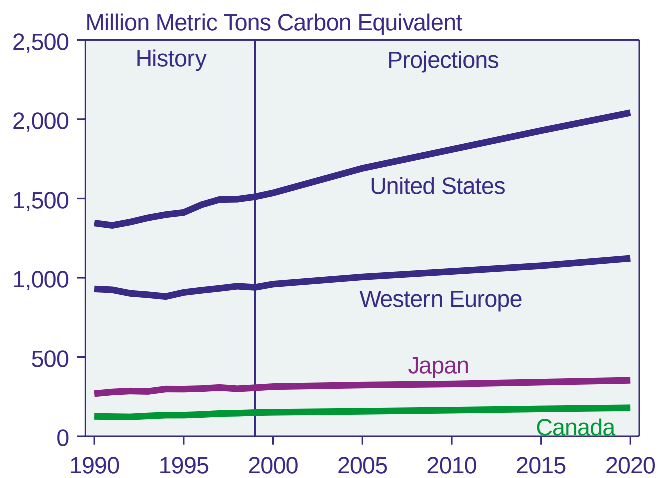
Canada accounted for 11 percent of North America's energy use during the 1990s. Energy use in Canada has been less carbon-intensive than in the United States

Figure 96. Carbon Dioxide Emissions by Region and Fuel Type, 1999 and 2020



Sources: **1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2020:** EIA, World Energy Projection System (2001).

Figure 97. Carbon Dioxide Emissions in the Industrialized World, 1990-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

(Table 24). In the 1990s, Canada relied on renewable energy sources (predominantly hydroelectric power) to meet approximately 30 percent of its total energy demand, as compared with 7 to 8 percent in the United States. Canada also has significant fossil fuel reserves, but coal, the most carbon-intensive fossil fuel, accounts for a smaller share of energy use in Canada than it does in the United States.

In Canada's electric power sector, hydropower accounted for 62 percent of the total energy consumed for electricity generation in 1999 and nuclear power 14 percent. Fossil-fired generation capacity is expected to

Table 24. Carbon Intensities of Energy Use for Selected Countries and Regions, 1990, 1999, 2010, and 2020
(Million Metric Tons Carbon Equivalent per Quadrillion Btu)

Country or Region	1990	1999	2010	2020
United States	16.02	15.62	15.85	16.06
Canada	11.57	11.67	10.75	10.81
Mexico	16.81	16.40	16.63	16.98
United Kingdom	17.86	15.49	15.87	15.78
Germany	18.33	16.45	15.90	15.84
France	11.00	9.94	9.56	9.82
Japan	15.02	14.12	14.04	13.61
Australasia	18.15	18.46	18.07	17.83
Former Soviet Union	16.97	15.46	15.35	15.35
Eastern Europe	19.65	18.00	16.41	14.36
China	22.85	20.92	20.44	20.01
India	19.67	19.88	19.05	18.23
South Korea	16.57	14.63	14.01	13.29
Middle East	17.63	17.07	16.76	16.86
Africa	19.21	18.50	18.19	17.93
Central and South America	12.97	12.62	13.29	13.85

Sources: **1990 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

increase over the projection period as more natural-gas-fired capacity is added and aging nuclear power plants are shut down, but Canada's overall carbon intensity is not expected to change significantly. The 20-percent projected growth in energy-related carbon dioxide emissions in Canada is largely attributable to expected strong economic growth.

Mexico had the smallest share of North America's energy use and energy-related carbon dioxide emissions during the 1990s, although its carbon intensity was somewhat higher than that in the United States. As a major non-OPEC oil producer, Mexico's overall energy mix and electricity generating portfolio have relied heavily on oil. Natural gas is the next most important source of overall energy consumption, although its market share is less than renewables (principally hydropower) in terms of energy consumed for electricity generation.

With a projected rate of economic growth that is higher than for any other country in the industrialized world and an expected rate of decline in energy intensity that is comparable with those for most of the other industrialized countries, Mexico's carbon dioxide emissions are expected to increase at the region's fastest rate. Average annual increases of 3.4 percent are projected as carbon dioxide emissions rise from 101 million metric tons carbon equivalent in 1999 to 203 million in 2020. Nevertheless, Mexico still is expected to account for less than one-tenth of North America's total energy-related carbon dioxide emissions.

Western Europe

Energy-related carbon dioxide emissions in Western Europe are projected to increase from 940 million metric tons carbon equivalent in 1999 to 1,123 million metric tons carbon equivalent in 2020. The region's overall carbon intensity declined on average by 1 percent per year from 1990 to 1999 as a significant portion of its energy use shifted from coal to natural gas and nuclear energy. During the same period, total energy consumption increased by 1.1 percent per year. Consequently, there was almost no net change in the region's carbon dioxide emissions from 1990 to 1999.

The decline in Western Europe's coal consumption is projected to continue in the *IEO2001* forecast as natural gas consumption, particularly for electricity generation, increases. Renewable energy use is also projected to increase, but decreases in nuclear power generation over the forecast period are projected to slow the decline in carbon intensity. Germany's new coalition government recently committed to a complete phaseout of domestic nuclear power generation, with the last plant closure expected to occur in the mid-2020s [***4***]. Belgium, Sweden, the Netherlands, and Spain have also committed to shutting down their nuclear power industries.

Industrialized Asia

Japan, the world's second largest economy and fourth largest energy consumer, was responsible for most of industrialized Asia's carbon dioxide emissions in the 1990s, although its carbon intensity ranked at the low end among industrialized countries (along with France and Canada), primarily due to its continued reliance on nuclear energy for reasons of national energy security. Nuclear energy represented 33 percent of Japan's electricity consumption in 1999, up by 6 percentage points from 1990. Over the forecast period, Japan's carbon dioxide emissions are projected to increase by 15 percent as a result of increasing energy demand (prompted by a gradual upswing in economic growth) and increasing carbon intensity. Although the government plans to increase nuclear generation, natural gas is expected to capture a larger share of the fuel market for electricity generation and for other uses.

In contrast to Japan, Australasia had one of the highest carbon intensities in the industrialized world, at approximately 18 million metric tons carbon equivalent per quadrillion Btu throughout most of the 1990s. Patterns of energy use vary across this region, which includes Australia, New Zealand, and the U.S. Territories. Australia accounts for the majority of Australasia's energy consumption, and with large domestic fossil fuel reserves, it has relied heavily on coal and oil to meet its energy needs. Australasia's energy consumption is expected to increase steadily over the forecast period. A slight decline in carbon intensity is expected, with natural gas use growing more rapidly than coal use. Overall, however, Australasia's energy-related carbon dioxide emissions are projected to increase by 25 percent, to 144 million metric tons carbon equivalent in 2020.

Eastern Europe and the Former Soviet Union

Energy consumption and carbon dioxide emissions in the EE/FSU region have declined significantly in the wake of political and economic changes since 1990. For most countries in the region, the transition to a market-oriented economy has been accompanied by lower industrial activity and per capita income. The FSU countries encountered further economic setbacks as a result of the 1998 Russian financial crisis and civil conflicts in Russia and other countries in the Commonwealth of Independent States. Between 1990 and 1999, energy consumption declined by 27 percent in Eastern Europe and by 36 percent in the FSU. The concomitant declines in carbon dioxide emissions in the two regions were slightly greater (33 percent and 41 percent, respectively), because their carbon intensities also decreased. Coal production and consumption in the EE/FSU declined as a result of economic reforms and industry restructuring, and the natural gas and nuclear shares of the energy mix increased.

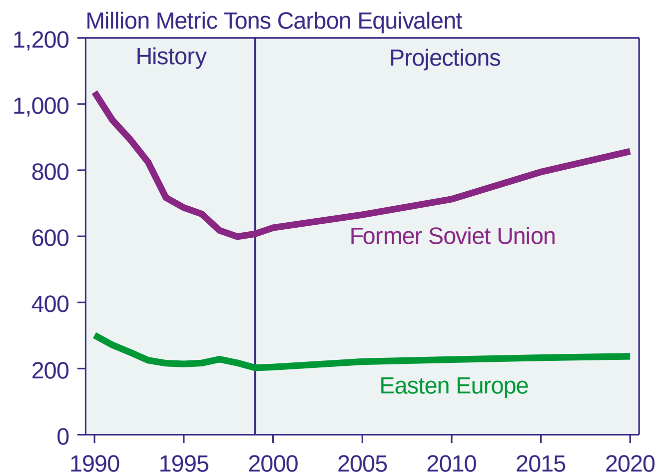
Given the expectations for economic recovery in the FSU and further economic expansion in Eastern Europe, energy consumption and carbon dioxide emissions in the EE/FSU region are projected to increase over the forecast period. The majority of the projected increase in EE/FSU emissions is expected in the FSU, where carbon intensity is projected to remain largely unchanged. With the further development of the vast natural gas reserves in Russia and the Caspian Sea region, natural gas is expected to continue to displace coal use in the FSU, but carbon-intensive oil consumption is also expected to increase, and nuclear energy use is expected to decline as Soviet-era nuclear reactors are retired. Total carbon dioxide emissions in the FSU are projected to increase by 250 million metric tons carbon equivalent between 1999 and 2020, but at 857 million metric tons carbon equivalent in 2020 they would still be lower than the 1990 level of 1,036 million metric tons carbon equivalent (Figure 98).

In Eastern Europe, coal accounted for 40 percent of the overall fuel mix and 56 percent of the energy consumed for electricity generation in 1999. With further restructuring of the coal mining industry in Poland and the Czech Republic, declines in coal production and consumption are expected to continue. Between 1999 and 2020, natural gas use is projected to more than triple, whereas coal consumption is projected to decline by half. As a result, the region's carbon intensity is expected to decline by 20 percent—more than in any other region of the world. Even at that rate, however, the decline in Eastern Europe's carbon intensity would not keep pace with the expected growth in total energy consumption (47 percent). Consequently, carbon dioxide emissions in the region are expected to increase from 203 million metric tons carbon equivalent in 1999 to 237 million in 2020.

Developing Countries

In the developing countries, carbon dioxide emissions from the combustion of all fossil fuels are projected to increase, although emissions from the combustion of

Figure 98. Carbon Dioxide Emissions in the EE/FSU Region, 1990-2020



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **Projections:** EIA, World Energy Projection System (2001).

coal and oil are expected to grow more slowly than those from natural gas. Coal is expected to remain a major source of energy-related carbon emissions in the developing world, most notably in China and India, where heavy reliance on coal consumption is projected to continue throughout the projection period. Nevertheless, coal's share of total carbon dioxide emissions in the developing world is projected to decline from 42 percent in 1999 to 38 percent in 2020. The oil share is expected to remain steady at 45 percent, and the natural gas share is expected to increase from 13 percent to 17 percent.

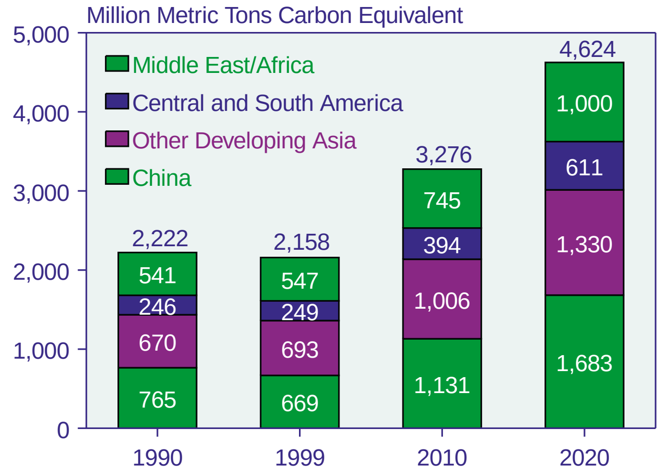
Carbon dioxide emissions in the developing world increased at a robust rate throughout most of the 1990s as a result of rapid economic expansion, growing demand for energy, and relatively minor decreases in carbon intensity. Overall, energy consumption increased by 40 percent between 1990 and 1999, and carbon dioxide emissions increased by 31 percent. Most of the growth in energy use and carbon dioxide emissions in the developing world occurred in Asia. Despite the economic recessions that followed the Asian financial crisis of 1997, average annual rates of economic growth in the nations of developing Asia were higher than in any other region during the 1990s. Continued economic growth and population growth over the forecast period are projected to further increase energy consumption in the developing world, particularly coal use for electricity generation and oil consumption for transportation services. As a result, in the *IEO2001* reference case carbon dioxide emissions in the developing world are projected to more than double, from 2,158 million metric tons carbon equivalent in 1999 to 4,624 million in 2020 (Figure 99).[32]

Currently, carbon intensities in developing Asia rank highest among the developing countries and on a worldwide basis. China and India rely heavily on domestic supplies of coal for electricity generation and industrial activities, the emissions from which have contributed to the worsening of air quality in those countries. In 1999, coal accounted for 61 percent of total energy consumption in China and 52 percent in India, with the remaining share of energy consumption in each country dominated by oil. As a result, their carbon intensities were 21 and 20 million metric tons carbon equivalent per quadrillion Btu, respectively. Because oil rather than coal is the predominant fuel consumed in South Korea and other developing areas of Asia, their carbon intensities were somewhat lower than those for China and India.

Based on expectations of continued economic expansion and population growth in developing Asia, energy consumption in developing Asia is projected to more than double between 1999 and 2020. The projection for developing Asia's carbon dioxide emissions follows suit. In China, where coal reserves are abundant and access to other energy fuels is limited in many parts of the country, coal is expected to continue to be the primary source of energy. India's carbon intensity is projected to decline more rapidly than China's due to a more pronounced shift away from coal. The use of natural gas, nuclear energy, and renewables for electricity generation is projected to increase significantly in India, although coal consumption is still expected to represent a large share of total energy consumption, particularly in India's heavy industry sector. Coal's share of total energy consumption is also projected to decline in South Korea and other developing Asia as natural gas use increases.

In Central and South America, carbon intensity was relatively low in the 1990s because hydropower fueled the majority of the region's electricity generation. In 1999, renewable energy sources (primarily hydropower) accounted for 94 percent of the energy consumed for electricity generation in Brazil and 59 percent in other Central and South America. Over the forecast period, carbon intensity in Central and South America is projected to increase as a result of efforts to lessen dependence on hydropower. Carbon dioxide emissions in the region are projected to increase by 4.4 percent per year on average between 1999 and 2020, while energy consumption is projected to grow at a slightly slower pace.

Figure 99. Carbon Dioxide Emissions in the Developing World, 1990, 1999, 2010, and 2020



Sources: **1990 and 1999:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** EIA, World Energy Projection System (2001).

[32]Compared with the industrialized world, a much larger share of energy consumption in the developing world (especially Africa and Asia) comes from biomass—including wood, charcoal, and agricultural residues. Because data on biomass use in developing countries are often sparse or inadequate, *IEO2001* does not include the combusion of biomass fuels in its coverage of current or projected energy consumption.

Environmental Impacts of Hydropower

It is estimated that approximately one-third of the countries in the world currently rely on hydropower for more than half of their electricity supply. Largely considered a "clean" renewable energy source, hydropower has provided many economic and social benefits. Many countries have chosen to develop their hydroelectric resources as a means of improving domestic energy security, providing more energy services, stimulating regional economic development, and increasing economic growth. For example, Brazil started to invest heavily in hydroelectric development in the 1970s, after experiencing the world oil price shocks and their effects on national energy supply and, particularly, electricity costs. Hydroelectric development in Brazil, which has resulted in some of the world's largest hydropower plants, bolstered growth in the country's heavy industry sector and helped achieve a high level of electrification.

The benefits provided by hydroelectric development in Brazil and other countries were not achieved without also incurring some negative economic, social, and environmental impacts. In particular, large hydroelectric facilities have tended to demonstrate variable economic performance, and in some cases they have been blamed for increasing the debt burden of developing countries. Most of the negative social and environmental impacts are associated with hydroelectric reservoirs (as well as reservoirs and dams for other purposes), rather than hydropower itself.

It is now widely recognized that dam development, whether for hydropower or other purposes, can disrupt the culture and sources of livelihood of many communities. Studies have indicated that the majority of the people uprooted from their existing settlements as a result of dam development are poor and / or members of indigenous populations or vulnerable ethnic minorities. Displaced populations are also more likely to bear a disproportionate share of the social and environmental costs of large dam projects without gaining a commensurate share of the economic benefits. The negative environmental impacts of dams and their reservoirs include loss of forests, wildlife habitats, species populations, aquatic biodiversity, upstream and downstream fisheries, and services provided by downstream flood plains and wetlands.[a]

With the emergence of climate change as an environmental issue of increasing international concern, hydropower has largely been viewed as a "cleaner" energy source than fossil fuels. No carbon dioxide or other greenhouse gas emissions result from the generation of hydroelectricity, because no fuel combustion is involved. However, results from preliminary field studies indicate that the reservoirs associated with hydroelectric dams emit both carbon dioxide and methane. Emissions emanate from the decomposition of biomass in the reservoirs and from biomass flowing in from the river's catchment area. The scale of emissions is variable, depending on the reservoir location (geography, altitude, latitude), temperature, size, depth, depth of turbine intakes, dam operations, and construction procedures.[b] Additional greenhouse gases are also emitted in the process of making cement for dam construction.

The recently discovered evidence of hydroelectric-related greenhouse gas emissions has obvious implications for energy choices made in light of climate change considerations. Some field studies suggest that greenhouse gas emissions from hydroelectric reservoirs (the sum of carbon dioxide and methane, based on their global warming potentials) can be similar in magnitude to those from thermal power plants with equivalent generation capacity. (Because specific site conditions determine the levels of emissions from hydroelectric reservoirs, comparisons must be made on a case-by-case basis.) On the other hand it has been argued that the true measure of "anthropogenic" emissions associated with a hydroelectric plant can only be assessed by comparison with emissions from the same catchment area before the dam was constructed.[a]

[a]World Commission on Dams, *Dams and Development: A New Framework for Decision-Making* (London, UK: Earthscan Publications, 2000).

[b]World Commission on Dams, "Hydropower and Climate Change: WCD Reviews Evidence on Large Dams and Greenhouse Gas Emissions," Press Release (June 10, 2000), web site www.dams.org.

In 1999, carbon intensities in Africa and the Middle East—at 19 and 17 million metric tons carbon equivalent per quadrillion Btu, respectively—were close to the average for the developing world. Oil was the most widely used fuel in both regions, although Africa relied more extensively on coal for electricity generation. In both regions, coal consumption is expected to decline relative to oil consumption over the forecast period, resulting in similarly slight decreases in carbon intensity. Carbon dioxide emissions are expected to grow more rapidly in the Middle East than in Africa, due to the higher projected rate of growth for energy demand in the Middle East.

Issues in Climate Change Policy

The Framework Convention on Climate Change

To date, the world community's effort to address global climate change has taken place under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in May 1992 and entered into force in March 1994. The ultimate objective of the UNFCCC is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [*5*]. The most ambitious proposal coming out of the subsequent conferences of the parties has been the Kyoto Protocol, which was developed by the third conference of the parties (COP-3) in Kyoto, Japan, in December 1997. The terms of the Kyoto Protocol call for Annex I countries to reduce their overall greenhouse gas emissions by at least 5 percent below 1990 levels over the 2008 to 2012 time period. Quantified emissions targets are differentiated for most countries covered under the Protocol.[33]

In addition to domestic emission reduction measures, the Kyoto Protocol allows four "flexibility mechanisms" to be used by Annex I countries in meeting their emission targets:

- *International emissions trading* allows Annex I countries to transfer some of their allowable emissions to other Annex I countries, beginning in 2008. For example, an Annex I country that reduces its 2010 greenhouse gas emissions level by 10 million metric tons carbon equivalent more than needed to meet its target level can sell the "surplus" emission reductions to other Annex I countries. The trade would lower the seller's allowable emissions level by 10 million metric tons carbon equivalent and raise the buyers' allowances by the same amount.

- *Joint fulfillment* allows Annex I countries that are members of an established regional grouping to achieve their reduction targets jointly, provided that their aggregate emissions do not exceed the sum of their combined Kyoto commitments. For example, European Union (EU) countries have adopted a burden-sharing agreement that reallocates the aggregate Kyoto emission reduction commitment for the EU among the member countries [*6*].

- *The clean development mechanism* (CDM) allows Annex I countries, either through the government or a legal entity, to invest in emission reduction or sink enhancement projects in non-Annex I countries, gain credit for those "foreign" emissions reductions, and then apply the credits toward their own national emissions reduction commitments. The CDM, in principle, redistributes emission reductions from developing country parties to Annex I parties.

- *Joint implementation* (JI) is similar to the CDM, except that the investment in emission reduction projects occurs in Annex I countries.

The Kyoto targets refer to overall greenhouse gas emission levels, which encompass emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Hence, a country may opt for relatively greater reductions of other greenhouse gas emissions and smaller reductions of carbon dioxide, or vice versa, in order to meet its entire Kyoto obligation. Currently, it is estimated that carbon dioxide emissions account for a large majority of overall greenhouse gas emissions in most Annex I countries, followed by methane and nitrous oxide[*7*].

The Kyoto Protocol also looks beyond energy-related sources of carbon dioxide.[34] Changes in emission levels resulting from human-induced actions that release or remove carbon dioxide and other greenhouse gases from the atmosphere via terrestrial "sinks" (trees, plants, and soils) are also addressed under the Protocol. While the conference of the parties is still working to reach a consensus on an equitable accounting method for sinks, the Protocol could allow emission reductions resulting from actions such as reforestation to serve as an alternative means for a country to achieve its overall Kyoto commitment.[35] The extent to which each Annex I country makes use of the Kyoto mechanisms will also influence the amount of domestic emission reductions needed to comply with the Protocol.

IEO2001 projects only emissions of energy-related carbon dioxide, which, as noted above, account for the bulk of Annex I emissions. The *IEO2001* reference case projections indicate that energy-related carbon dioxide emissions from the Annex I countries will exceed the group's 1990 emissions level by 10 percent in 2010. Industrialized Annex I countries emitted 3,022 million metric tons carbon equivalent from energy use in 1999 and are projected to emit 3,475 million metric tons by 2010. Taking the prescribed Kyoto emission reduction targets on the basis of energy-related carbon dioxide emissions alone,

[33]Turkey and Belarus, which are represented under Annex I of the UNFCCC, do not have quantified emission targets under the Kyoto Protocol. The Protocol does include emission targets for 4 countries not listed under Annex I (Croatia, Liechtenstein, Monaco, and Slovenia). Collectively, the 39 Parties (38 countries plus the European Union) with specific emissions targets under the Kyoto Protocol are referred to as "Annex B Parties," because their targets are specified in Annex B of the Protocol.

[34]Annex A of the Kyoto Protocol lists all the sector and source categories for all greenhouse gas emissions covered under the agreement.

[35]Article 3.3 of the Kyoto Protocol allows Annex I Parties to count toward their emission targets net changes in greenhouse gas emissions resulting specifically from afforestation, reforestation, and deforestation since 1990. Article 3.4 leaves the door open for the inclusion of other land use and forestry activities that release (emit) or remove (uptake) greenhouse gases.

the industrialized Annex I countries would face an emission limit of 2,573 million metric tons carbon equivalent in 2010—a 26-percent difference from their projected baseline emissions[36] (Figure 100). On the other hand, energy-related carbon dioxide emissions from the group of transitional Annex I countries have been decreasing throughout the 1990s as a result of economic and political crises in the EE/FSU. Baseline emissions from the transitional Annex I countries are projected to reach 802 million metric tons carbon equivalent in 2010, still 30 percent below their combined Kyoto reduction target.

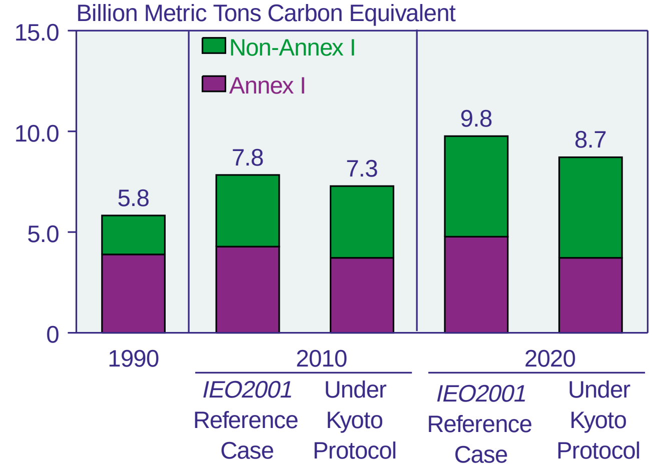
Details regarding the operation of the Kyoto Protocol have been the subject of several UNFCCC meetings since COP-3. In November 1998, COP-4 took place in Buenos Aires, Argentina, where delegates determined a schedule, called the Buenos Aires Plan of Action, for reaching agreement on precisely how the Protocol is to operate. Among the more contentious topics of negotiation were the regime for monitoring compliance with emission reduction commitments, the treatment of terrestrial greenhouse gas sinks, and rules governing the use of the Kyoto flexibility mechanisms.

The Buenos Aires Plan of Action set COP-6 as the deadline for resolving the operational details of the Kyoto Protocol. However, the COP-6 negotiations, which took place in November 2000 in The Hague, the Netherlands, ended without agreement. Rather than concluding negotiations without a resolution, the UNFCCC delegates agreed to suspend COP-6 and to reconvene in the summer of 2001.

National and Regional Greenhouse Gas Emissions Trading

Despite the current uncertainty about the fate of the Kyoto Protocol, several countries are establishing or considering domestic programs specifically aimed at reducing their own greenhouse gas emissions from energy use. The programs are diverse in coverage and approach, ranging from government-sponsored incentive programs to encourage voluntary emissions reductions by industry or geographic region to mandatory carbon tax schemes for lowering carbon-intensive energy use. In some countries, domestic emission trading schemes are being developed either independently or as a part of wider emission abatement programs. For the most part, the emission trading schemes use a "cap and trade" approach consistent with international emissions trading under the Kyoto Protocol, similar to the sulfur dioxide emissions trading program already in effect in the United States (see box on page 170).

Figure 100. Carbon Dioxide Emissions in Annex I and Non-Annex I Nations Under the Kyoto Protocol, 2010 and 2020



Sources: **1990:** Energy Information Administration (EIA), *International Energy Annual 1999*, DOE/EIA-0219(99) (Washington, DC, January 2001). **2010 and 2020:** World Energy Projection System (2001).

In 1999, Denmark became the first European country to establish its own emissions trading program, targeting carbon dioxide emissions from its electricity sector. The program was included as part of a larger electricity reform package that the Danish government developed in order to implement EU directives on electricity and gas market liberalization. The trading program, in conjunction with other energy-related initiatives, is intended to help Denmark meet its own national target of reducing carbon dioxide emissions to 20 percent below 1988 levels by 2005.[37] The trading program was originally scheduled to operate between 2000 and 2003, with the entire electricity sector facing an emissions cap of 23 million metric tons carbon equivalent in 2000, descending to 20 million metric tons in 2003. Issues related to electricity sector competition delayed the European Commission's approval of Denmark's reform package until May 2000, however, and the Danish government pushed back the start date for the carbon trading scheme to 2001.

In November 2000, the United Kingdom announced a new Climate Change Programme that incorporated a variety of policies geared toward reducing the country's overall greenhouse gas emissions to 23 percent below 1990 levels by 2010 [***8***]. Among other policies included in the UK's Climate Change Programme is a "climate change levy" (tax) on the energy content of natural gas, coal, and electricity used by businesses and public entities, starting on April 1, 2001. Government revenues

[36]The Kyoto Protocol emission targets are based on the average of emissions between 2008 and 2012 (the first commitment period). Because 2010 is the midpoint of the first commitment period, it is commonly used as the reference year for calculating emissions reductions under the Kyoto agreement.

[37]*Energy 21* is the action plan the Danish government put forward in 1996 to achieve by 2005 a 20-percent reduction in its total carbon dioxide emissions from their 1988 level. See web site www.ens.dk/uk/index.asp for further details on Danish energy policy and reforms.

Reducing Sulfur Dioxide and Nitrogen Oxide Emissions in the European Union and the United States

Many countries currently have policies or regulations to limit energy-related emissions of sulfur dioxide and nitrogen oxides. Both pollutants are known to contribute to the problems of acid rain and eutrophication of soils and waters, and nitrogen oxides also contribute to the formation of smog caused by ground-level (tropospheric) ozone. Coal-fired electricity generation both in the United States and in the European Union (EU). Electricity generation is also a source of nitrogen oxide emissions, but oil use for transportation is the largest source.

In Europe, efforts to limit sulfur dioxide and nitrogen oxide emissions were first coordinated under the 1979 United Nations/Economic Commission of Europe Convention on Long-Range Transboundary Air Pollution (CLRTAP), which was drafted after scientists demonstrated the link between sulfur dioxide emissions in continental Europe and the acidification of Scandinavian lakes. Since its entry into force in 1983, the Convention has been extended by eight protocols, setting emissions limits for a variety of pollutants. The most recent protocol, the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication, and Ground-Level Ozone, sets new national emissions ceilings for sulfur dioxide, nitrogen oxides, volatile organic compounds, and ammonia.

The national emissions ceilings under the Gothenburg Protocol correspond to a target reduction of total sulfur dioxide emissions in the EU of 75 percent below the 1990 level by 2010 and a 50-percent reduction in its nitrogen oxide emissions from the 1990 level by 2010.[a] Like the earlier CLRTAP protocols, the Gothenburg Protocol specifies tight limit values for specific emissions sources, based on the concept of critical loads, and requires best available technologies to be used to achieve the emissions reductions.

More specific measures for abating sulfur dioxide and nitrogen oxide emissions are defined in a number of European Commission directives. The Large Combustion Plant Directive of 1988 and its amendments impose sulfur dioxide and nitrogen oxide emission limits on existing and new plants with a rated thermal input capacity greater than 50 megawatts and sulfur dioxide emissions limits on smaller combustion plants using solid fuels (particularly coal). Other directives impose limits on the sulfur content of certain fuels used in power stations, industry, and motor vehicles; requirements for the use of best available technologies on new and existing plants (e.g., flue gas desulfurization devices, low nitrogen oxide burners); and vehicle emissions standards.

Since 1980, sulfur dioxide and nitrogen oxide emissions in Europe have fallen. The drop in sulfur dioxide emissions was partly due to prescribed emissions limits and technology requirements, particularly in the electricity generation sector. Shifts from coal to natural gas for electricity production in several countries during the 1990s (most notably in Germany and the United Kingdom) also contributed to the reduction. The same factors also contributed to the drop in nitrogen oxide emissions, but the introduction of catalytic converters on vehicles was the most influential factor.[b]

In the United States, initiatives to reduce sulfur dioxide and nitrogen oxide emissions stem from the Clean Air Act, the comprehensive Federal law that regulates air emissions from area, stationary, and mobile sources. The 1970 and 1977 Clean Air Act Amendments included emissions standards and requirements for the use of best available control technologies for new sources. The 1990 Amendments set emissions reduction goals for specific air pollutants and designated

(continued on page 171)

[a]For specific emission targets by country, see Annex II of the Gothenburg Protocol, web site www.unece.org.
[b]European Environment Agency, *Environmental Signals 2000* (Copenhagen, Denmark, 2000), web site www.eea.eu.it.

from the levy are to be recycled through a “carbon trust” that makes investments in alternative energy, energy-saving technologies, and other related programs. In the energy-intensive industries, large consumers will be offered an 80-percent rebate of the levy if they negotiate an agreement with the government for meeting an energy efficiency standard or absolute energy use cap. The negotiated standards and caps will be stated in terms of their associated carbon dioxide emission levels, essentially reflecting an emissions allowance for each firm. Under a proposed emissions trading scheme, the businesses that negotiate levy agreements will be able to trade their emission allowances. The government expects emissions trading to begin in April 2001.

Norway, which has had a carbon dioxide tax scheme on energy use in place since 1991, recently developed a comprehensive domestic emissions trading system that covers carbon dioxide and other greenhouse gas emissions from a wide variety of sources. The proposed Norwegian trading system is set to begin in 2008. If the Kyoto Protocol comes into force, Norway’s trading system will be open to tradable emission allowances from other Annex I parties and to certified emission reduction credits originating from the Kyoto clean development mechanism.

France, Germany, Sweden, and the Netherlands have indicated a desire to establish some form of domestic

Reducing Sulfur Dioxide and Nitrogen Oxide Emissions (Continued)

stricter emissions standards extending across a wider range of sources.

Title IV of the Clean Air Act Amendments of 1990 (CAAA90) was intended to reduce the adverse effects of acid deposition by setting a goal of reducing annual sulfur dioxide emissions by 10 million tons below 1980 levels and annual nitrogen oxide emissions by 2 million tons below 1980 levels. To achieve the sulfur dioxide reductions, a two-phase tightening of emissions restrictions was placed on existing fossil-fired power plants serving utility generators with an output capacity greater than 25 megawatts and on all new utility units. Phase I, which began in 1995, affected mostly coal-burning electric utility plants in 21 eastern and southern States. Phase II, which began in 2000, tightened the annual emissions limits imposed on those large, higher emitting plants and also placed restrictions on smaller, cleaner plants fired by coal, oil, and gas.

CAAA90 Title IV established the world's first large-scale application of a "cap and trade" program to meet an environmental goal. Under the program, a total annual emissions budget (measured in tons of sulfur dioxide) was established for each year, in accordance with aggregate emissions reduction goals. Generating units were issued tradable emission allowances, based primarily on their historic fuel consumption and specific emissions rates. Each allowance permits a generating unit to emit one ton of sulfur dioxide during or after a given year. At the end of each year, power plant owners must hold an allowance for each ton of sulfur dioxide emitted that year, or else face a penalty. Extra allowances may be bought, sold, or banked (i.e., saved for future use rather than for current use).

Emissions data from Phase I indicate overcompliance: the generating units subject to the Phase I emissions cap emitted, in aggregate, less sulfur dioxide than the total allowable level. Emissions were reduced by a combination of strategies, including the installation of scrubbers, switching to low-sulfur coal, and trading emission allowances.[c] It is argued that without the trading option, the reduction in sulfur dioxide emissions that was over and above the required amount would not have been as large.[d] Phase II of the program, which is currently in effect, sets a permanent ceiling (cap) of 8.95 million tons on the allowances issued each year; however, the amount of sulfur dioxide actually emitted may exceed the Phase II cap for some time, because allowances banked under Phase I can be carried over to Phase II.

The nitrogen oxide emissions reductions required by CAAA90 Title IV were also scheduled according to a two-phase approach, but no cap was set for aggregate nitrogen oxide emissions from electricity generation, and no allowance trading program was included. Phase I, which began in 1996, set an emissions limit (in pounds of nitrogen oxide per million Btu of fuel input) for two types of coal-fired utility boilers already targeted for Phase I sulfur dioxide emissions reductions. Phase II, which started in 2000, set stricter nitrogen oxide emissions limits for those boiler types and established emissions limits for other coal-fired boiler types.

Other programs for reducing nitrogen oxides and sulfur dioxide emissions in the United States have been established as a result of the Clean Air Act Amendments. In an effort to reduce the transport of emissions over long distances and help States meet the national ambient air quality standards for ground-level ozone, the U.S. Environmental Protection Agency has promulgated a multi-State summer season cap on power plant nitrogen oxide emissions that will take effect in 2004. The new rules, commonly referred to as the "NO_x SIP Call," require abatement efforts greater than those required to comply with the limits on nitrogen oxides under CAAA90 Title IV. The limits under the NO_x SIP Call have been set in the form of allowances and allowance trading is permitted.

CAAA90 also established emissions standards for motor vehicles. "Tier 1" standards cover emissions of nitrogen oxides (in addition to carbon monoxide, hydrocarbons, and particulate matter) for light-duty vehicles beginning with model year 1994, and the tighter "Tier 2" standards, which apply to all passenger vehicles, will be phased in starting in 2004. Tier 2 standards also require that the sulfur content of gasoline be reduced, in order to ensure the effectiveness of the emission control technologies that will be needed to meet the emission targets. Heavy-duty vehicles (trucks) have also faced emissions standards since 1990, which were easily met by engine controls. Recent rulings impose a new "ultra-low" sulfur content requirement for diesel fuel used by highway trucks and specific nitrogen oxide emissions control technologies by 2007.

[c]International Energy Agency, *Coal Information 2000* (Paris, France, August 2000).

[d]A.D. Ellerman, *Tradeable Permits for Greenhouse Gas Emissions: A Primer with Particular Reference to Europe* (Cambridge, MA: MIT Joint Program on the Science and Policy of Global Change, Report No. 69, November 2000).

emissions trading, but they have not put forth any specific trading proposals. The EU is also considering establishing an emissions trading program for large electric utilities and industrial sources, starting in 2005 [***9***].Under the EU program, emissions trading would be limited to carbon dioxide until 2008, with a possible expansion to include other greenhouse gases and sinks after 2008. However, the establishment of any emissions trading scheme in those countries or across the EU may be contingent upon their plans for implementing the Kyoto Protocol [***10***].

Federal and provincial governments in Canada have supported two pilot programs aimed at providing businesses and government with practical experience in emissions trading and assessing the benefits of such programs. Ontario's PERT trading program runs from 1996 to 2001, covering air pollutants (including greenhouse gases), and the GERT trading program runs from 1998 through 2001, covering greenhouse gas emission reductions from six Canadian provinces and the federal government.

The Prototype Carbon Fund

Several governments and businesses have begun to invest in carbon dioxide emission reduction projects through the World Bank's Prototype Carbon Fund, which was established in July 1999. The fund functions as a public-private partnership that aims to mobilize new and additional resources to address climate change and promote sustainable development. Contributions to the Prototype Carbon Fund from governments and businesses, which are capped at $150 million, are invested primarily in renewable energy and energy efficiency projects in developing countries and countries with economies in transition. The contributors, or "participants," receive a *pro rata* share of the emission reductions resulting from the projects, which are verified and certified in accordance with carbon purchase agreements reached with the countries "hosting" the projects.

The Prototype Carbon Fund formally started operating on April 10, 2000, and is scheduled to terminate in 2012. As of the end of September 2000, it had six participant governments and 17 participant companies, with total capitalization of $145 million.[38] In order to be compatible with the Kyoto Protocol, should it come into force, the Prototype Carbon Fund seeks to invest in projects that produce greenhouse gas emission reductions fully consistent with the emerging framework for joint implementation and clean development mechanism projects. Of the 25 projects under consideration for investment as of September 2000, 5 have already been endorsed as clean development mechanism or joint implementation projects by their host governments [***11***].

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[38]As of September 2000, the six participant governments in the Prototype Carbon Fund were Canada, Finland, the Netherlands, Norway, Sweden, and the Japan Bank for International Cooperation.